AD-A103 547 MASSACHUSETTS INST OF TECH LEXINGTON LINCOLN LAB F/G 14/2
AUTOMATED PHASE/AMPLITUDE EHF MEASUREMENT SYSTEM.(U)
MAY 81 B M POTTS F19628-80-C-0002
UNCLASSIFIED TR-560 ESD-TR-81-99 NL

1 OF 1
AD A
103547

END
DATE
FILMED
10-81
DTIC

ESD-TR-81-90

LEVEL II

12

AD A103547

Technical Report 560

B.M. Potts

Automated Phase/Amplitude EHF Measurement System

28 May 1981

Prepared for the Department of the Air Force
under Electronic Systems Division Contract F19628-80-C-0002 by

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Lexington, Massachusetts

The work reported in this document was performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, with the support of the Department of the Air Force under Contract F19628-80-C-0002.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Raymond L. Loiselle

Raymond L. Loiselle, Lt.Col., USAF
Chief, ESD Lincoln Laboratory Project Office

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

AUTOMATED PHASE/AMPLITUDE EHF MEASUREMENT SYSTEM

R.M. POTTS

Group 61

TECHNICAL REPORT 560

28 MAY 1981

Approved for public release; distribution unlimited.

LEXINGTON MASSACHUSETTS

ABSTRACT

An automated, computer-controlled measurement system capable of conducting transmission and reflection measurements on components over the 40 to 47 GHz frequency range is described. The measurement system utilizes harmonic mixing in conjunction with a phase locked, dual channel receiver to downconvert signals in the 7 GHz bandwidth to a lower intermediate frequency (1 KHz) where phase and amplitude measurements are made.

The system is capable of operating over a dynamic range in excess of 50 dB when used with an EHF source producing a minimum -10 dBm output. Following a description of the system and its operation, some performance characteristics are presented. The measurement system accuracy is demonstrated using two types of reference standards: (1) a rotary vane attenuator for the transmission measurements, and (2) a set of reduced-height waveguide VSWR standards for the return loss measurements. Results obtained using these standards have indicated that measurement accuracies of 0.25 dB and 3^{o} are achievable over a 50 dB dynamic range.

CONTENTS

LIST OF ILLUSTRATIONS

I. INTRODUCTION

Because of the increasing sophistication of components designed for millimeter wavelengths, it is becoming more important to characterize the performance of these components in terms of their phase and amplitude responses. Unfortunately, commercially available network analyzers capable of measuring complex s-parameters are for the most part limited to frequencies below 18 GHz. Above 18 GHz there is a marked absence of automated network analyzers capable of measuring phase. Consequently, at these frequencies metrologists have had to either resort to performing scalar (amplitude only) measurements, or construct their own phase measurement system.

In this report an automated measurement system capable of measuring the complex transmission loss (s_{12}, s_{21}) and return loss (s_{11}, s_{22}) of components over the 40-47 GHz frequency range is described. The measurement system is built around the Scientific-Atlanta Series 1750 phase/amplitude receiver, a receiver originally designed for use in performing antenna radiation pattern measurements. Because the receiver was designed to be operated manually at fixed frequencies, several modifications were necessary to automate its operation. These modifications, along with a description of the measuring system and its operation, are discussed in Section II. The receiving system utilizes harmonic mixing in conjunction with the phase locked dual channel 1750 receiver to downconvert signals in the 7 GHz bandwidth to a lower intermediate frequency (1 KHz) where phase and amplitude measurements are made. The performance characteristics of this system are presented in Section III along with a comparison of the measured vs theoretical results obtained using two types of reference standards: (1) a rotary vane attenuator for the transmission measurements, and (2) a set of reduced-height waveguide VSWR standards for the return loss measurements.

II. SYSTEM DESCRIPTION

Shown in Fig. 1 is a block diagram of the measurement system. It is comprised of four main subsystems:

1. A programmable EHF source,
2. A reflection/transmission network,
3. An automated phase/amplitude receiver, and
4. A system controller and data interface.

Frequencies from 40 to 47 GHz are generated by mixing the frequency doubled output of a 19 GHz Gunn local oscillator (LO) with a 2 to 9 GHz intermediate frequency (IF) to produce an output frequency given by

$$f_{RF} = 2f_{LO} + f_{IF} \tag{1}$$

The image frequency ($2f_{LO}-f_{IF}$), and spurious frequencies harmonically related to the LO and IF (i.e., $nf_{LO} \pm mf_{IF}$) are suppressed by filtering circuits within the upconverter and by the 40-47 GHz bandpass filter (BPF). Since the IF input signal is synthesized, the stability of the output frequency is determined primarily by the frequency stability of the LO. Because Gunn LOs typically exhibit long term frequency variations due to ambient temperature changes on the order of -0.5 to -1 MHz/^{o}C, the output frequency, if left uncorrected, would vary on the order of -1 to -2 MHz/^{o}C. Although this amount of frequency drift is generally acceptable for most measurement requirements, the technique used in tuning and phase locking the receiver is based on knowing the source frequency very precisely. For this reason, the output frequency is stabilized by counting the Gunn LO frequency (just prior to a measurement) and correcting for frequency drifts by resetting the IF source frequency. With this technique the output frequency can be maintained within 75 KHz of the desired frequency (i.e., ~2 ppm at 44 GHz) over time intervals of several seconds, corresponding to several measurement periods. In

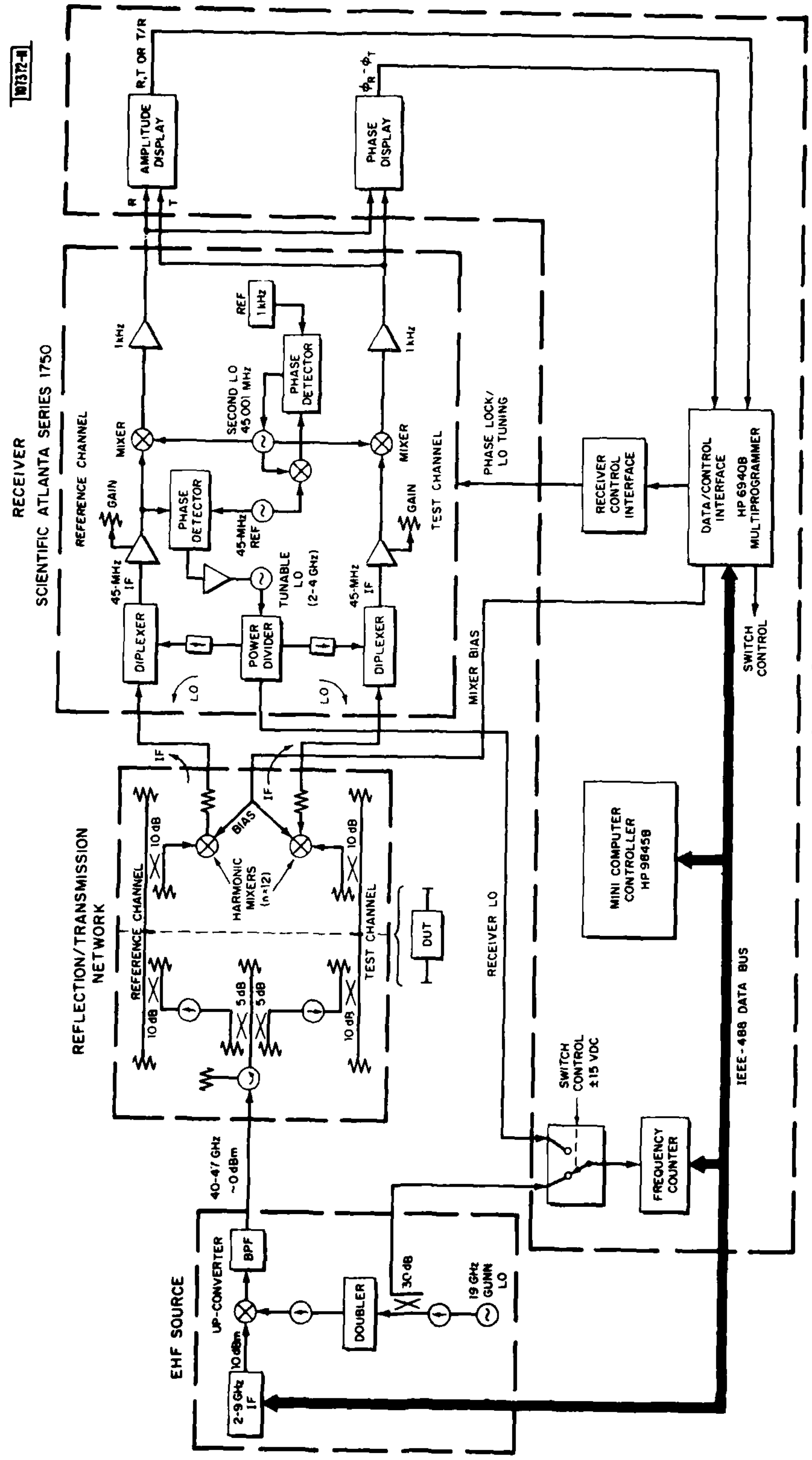

Fig. 1. System block diagram.

addition, by controlling the drive level of the IF source (using a stored calibration), one can also obtain a leveled output. For a nominal +10 dBm input signal, the output level of the upconverter can be maintained within the range -1 dBm $\pm$ 1 dB over the 40-47 GHz band. The upconverter is capable of operating over a wider frequency range with somewhat reduced performance. In the present system configuration the frequency range is limited by the 2 GHz lower frequency limit of the IF synthesizer, and by the 40-47 GHz bandwidth of the output filter.

The EHF source and receiver are connected together by the reflection/transmission network (RTN). This network uses a dual-directional coupler for separating the input signal into a test channel containing the device-under-test (DUT) and a reference channel which contains the reference signal required for phase locking the receiver. Isolators connected to the outputs of the coupler are used to reduce channel cross-talk by minimizing the reflection and coupling of signals between channels. The pair of 10 dB directional couplers in the test and reference channels are added to minimize impedance mismatch errors by reducing the VSWR produced when the DUT is inserted into the network. With these couplers added, the source VSWR and the load VSWR (as seen by the DUT) remain below 1.1 over the measurement band.

The RTN shown in Fig. 1 is configured to measure the transmission loss (or gain) and the insertion phase of a device inserted into the test channel. The system is calibrated by removing the DUT* from the RTN and measuring the amplitude and phase difference between the two channels. Ideally, to achieve maximum accuracy the DUT should be inserted into the network without changing the calibration. This, of course, is impossible since the simple operation of placing the DUT into the RTN involves opening and closing waveguide flanges and physically moving the waveguide, all of which can change the calibration. As a means of facilitating the removal and insertion of

*In some situations the system may be calibrated with the DUT in place. For example, in characterizing a variable attenuator where only relative attenuation changes are important, the system could be calibrated with the attenuator in place and set to its minimum value.

components into the RTN, the RTN was rigidly mounted on two separate plates which can be moved relative to each other on a sliding carriage. With this arrangement components having their input and output ports along the same axis can be inserted into (or removed from) the RTN simply by opening the appropriate flanges in the test and reference channels, sliding the network apart, inserting (removing) the component and reconnecting the flanges. Normally an equivalent length of waveguide is inserted into the reference channel to equalize the line lengths in the two channels. For components whose test ports are offset from each other (i.e., not colinear) or in situations where absolute loss is to be measured, it becomes necessary to physically move the 10 dB coupler and harmonic mixer in the test channel in order to reconnect the network. For these components there will be some error introduced into the calibration as a result of moving the harmonic mixer. This error occurs because of insertion phase changes resulting from the flexing of the transmission line used in connecting the mixer to the receiver. However, providing good phase-stable transmission lines are used, these errors are generally small and typically less than 1 or 2 degrees.

To measure return loss, the 10 dB coupler in the test channel is reversed, and the system calibrated by first attaching a short circuit to the directional coupler and measuring the frequency response of the two channels over the band. Directivity errors associated with the directional coupler are removed by replacing the short with a sliding load and using a sliding load technique to determine the complex directivity error correction coefficients at each frequency. The directivity coefficients are stored and later used in an error correction routine to subtract out the effects of the coupler directivity.

The receiving subsystem utilizes a superheterodyne, phase-locked receiver for linearly converting the EHF signals in the test and reference channels of the RTN to a lower frequency (1 KHz) where they can be compared more easily in amplitude and phase. This receiver was designed by the manufacturer (Scientific-Atlanta, Inc.) to be operated manually at fixed frequencies. Therefore, before incorporating it into the automated measurement system,

several modifications were necessary, one directed at automating the tuning of the receiver LO, and two additional modifications aimed at improving the performance of the receiver. A brief summary of these modifications is described below:

Mod. 1: Provided a means of externally tuning the receiver LO to enable the receiver to be tuned and phase locked under program control.

Mod. 2: Replaced the components used to distribute the LO signal to the harmonic mixers with better matched components to minimize LO phase dispersion.

Mod. 3: Improved the system sensitivity and measurement repeatability by providing a controllable dc bias to the harmonic mixers to minimize their conversion loss.

The downconversion of the EHF signals to 1 KHz is performed in two stages. The first conversion is carried out in the harmonic mixers where the EHF signals are mixed with a selected harmonic of the receiver LO frequency to produce an IF of approximately 45 MHz. The exact frequency of the first IF is determined by the frequency of a reference crystal oscillator located inside the receiver to which the signal is phase locked. Since the RF frequency and receiver IF are accurately known, the receiver LO frequency required to achieve phase lock can be computed as

$$f_{LO} = \frac{f_{RF} - f_{IF}}{n} \tag{2}$$

where n is the harmonic number. Phase locking of the output IF signal of the harmonic mixer with the receiver 45 MHz reference oscillator involves a sequence of operations based on counting the LO frequency and tuning the LO either up or down in frequency until its frequency is sufficiently close (~50 KHz) to the LO frequency (Eqn. 2) required to achieve phase lock. Because the receiver LO utilizes a mechanically-tuned, cavity-stabilized triode, frequency tuning is achieved by varying the cavity dimensions using a small direct-drive synchronous motor. The number of tuning operations

required to achieve phase lock varies somewhat from frequency to frequency, but tends to average approximately five tries per measurement point. The software automatically adjusts the LO tuning rate (in MHz/sec) so that when the LO is required to tune over large frequency spans (e.g., such as when the measurement points are widely separated), higher tuning rates are used to minimize the tuning time. As the LO frequency gets closer to the frequency required for phase lock, more control over the LO frequency is needed and slower tuning rates are used.

After the receiver has acquired the input signal, the 45 MHz signals in the test and reference channels are amplified, coupled to a second pair of mixers (inside the receiver) and combined with a second LO at 45.001 MHz to produce a 1 KHz signal. The 1 KHz signals are amplified in narrowband tuned amplifiers (BW~100 Hz) and outputted to amplitude and phase detection circuits where the signals are time-averaged, digitized and transferred over the data bus to the controller.

Operating the receiver over the 40 to 47 GHz frequency range requires using at least the 12th harmonic of the 2 to 4 GHz receiver LO to achieve the necessary downconversion of the EHF signals to the 45 MHz IF. This corresponds to tuning the LO over a 583 MHz bandwidth, from 3.330 to 3.913 GHz to cover the 7 GHz RF bandwidth. Although higher-order harmonics can be used at correspondingly lower LO frequencies, this serves no useful purpose since it only increases the already high conversion loss of the harmonic mixers (~40 dB for n=12).

The conversion loss of the harmonic mixers is influenced not only by the harmonic number, but also by the mixer LO power and dc bias. An effort was made to control the LO power by installing programmable attenuators in the LO signal paths leading to the harmonic mixers. This technique was found to be generally unreliable due to the inability to accurately control the attenuator settings which resulted in a worsening of the phase and amplitude repeatability. As an alternative to controlling the LO power directly, a more suitable arrangement was found based on varying the mixer dc bias. In this scheme the LO power is adjusted to a preset level over the band using fixed

attenuator pads connected to the output ports of the harmonic mixers. At each frequency the mixer bias was varied and the receiver output was measured. The mixer bias levels producing the largest output signal (i.e., minimum conversion loss) at each frequency are then stored in memory and used whenever the receiver is tuned to those frequencies.

Control over the measurement system is achieved using a desk-top calculator operating as an instrument controller over the IEEE-488 interface bus. Both the system calibration and component measurements are automated with the calculator controlling the EHF source frequency and power level, receiver operation, and data collection. A measurement sequence is initiated by having the operator input the EHF start and stop frequencies, the frequency increment, and certain other parameters relating to the integration times associated with the amplitude and phase data. The system is first calibrated by removing the DUT from the test channel of the RTN as described previously. At each frequency, the controller programs the EHF source, tunes the receiver LO to acquire phase lock and applies the appropriate dc bias to the harmonic mixers. As a means of reducing random errors in the calibration data, the calibrations are normally repeated several times and an average calibration computed. When making return loss measurements, the system is calibrated first with a short circuit, and then with a sliding load to determine the coupler directivity errors. Following the calibration, the DUT is inserted into the RTN and the measurements repeated in a manner similar to the calibration procedure. For transmission measurements the average measurement data is subtracted from the stored calibration data and the difference, which represents the frequency response of the DUT, is tabulated over the frequency band. In the case of return loss measurements, the directivity error coefficients associated with the directional coupler are used in an error correction routine to determine the error-corrected return loss data.

The total time required to conduct a single calibration (or measurement) run obviously depends upon the frequency range and number of frequencies to be measured. A single measurement run over a 7 GHz bandwidth from 40 to 47 GHz

at 71 frequencies (i.e., every 100 MHz) requires approximately 3 minutes using an integration period of 0.1 second/measurement, for an average of approximately 2.5 seconds per frequency.

III. EVALUATION OF SYSTEM PERFORMANCE

1. Dynamic Range, Linearity and Input Signal Levels

The measurement system dynamic range was determined by applying a fixed signal level to the reference channel harmonic mixer and varying the signal level to the test channel harmonic mixer. Fig. 2 illustrates results obtained at 44 GHz for two cases - when signal levels of -20 dBm and -30 dBm are applied to the reference channel mixer. For each case, the power level in the test channel was adjusted over a 50 dB range using a rotary vane attenuator, and the relative difference in amplitude and phase between the two channels measured. The results in Fig. 2(a) show that in both cases, measurements can be made over a minimum 50 dB range. The maximum input signal is limited by the saturation of the harmonic mixers which occurs at approxmately -15 to -20 dBm*. At this level the output response is compressed by approximately 1 dB compared to the ideal response of a linear mixer. The lowest useable signal level is determined by the system sensitivity, or more precisely, by the minimum output signal-to-noise (S/N) ratio which can be tolerated. For an input signal level of -70 dBm (as measured at the harmonic mixers) the S/N ratio of the 1 KHz IF output signal is approximately 25 dB, and at this level the uncertainty of the amplitude and phase readings is approximately ±0.25 dB and $\pm 1.5^{o}$, respectively, for a a 0.1 second integration of the output data.

Fig. 2(b) illustrates how the output phase varies as a function of the difference in signal level between the test and reference channel harmonic mixer. Since the signal level applied to the test channel harmonic mixer is reduced by the insertion (return) loss of the DUT when inserted into the RTN, Fig. 2(b) indicates how the phase accuracy degrades as a function of component loss. The results show that if the system is calibrated by applying the same power level to the test and reference channel, the resultant phase error for a component with 10 dB of insertion loss is generally less than one degree. As

*For the measurement system in Fig. 1, the maximum signal applied to the harmonic mixers is limited to approximately -25 dBm by the upconverter output level.

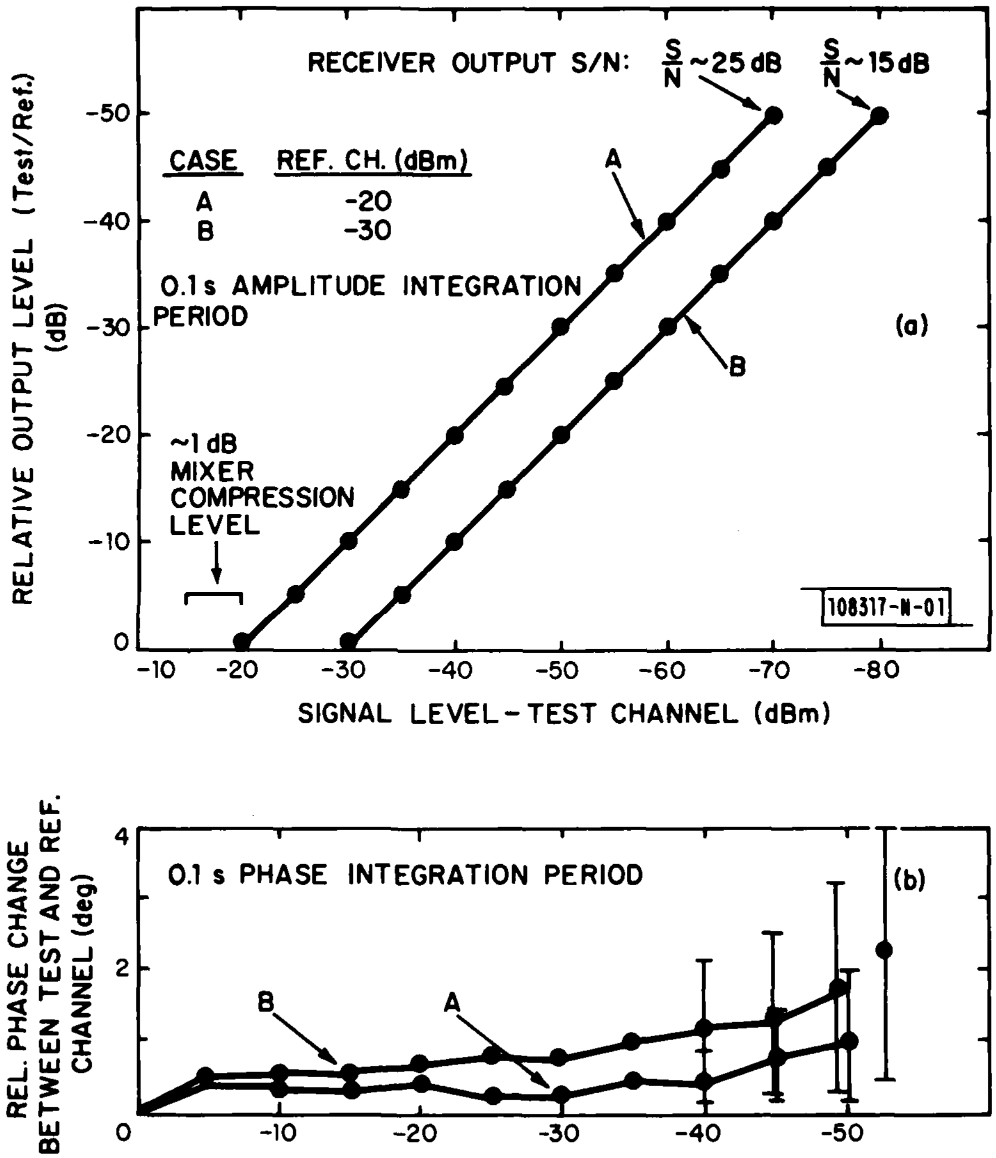

Fig. 2. Measured system performance at 44 GHz.

the difference in signal level between the two channels increases, so does the phase error, approaching 3^{o} for a 50 dB difference.

The stability of the measurement system is another important parameter since it determines how often the system must be recalibrated. The data presented in Fig. 3 is typical of the calibration results obtained over a one hour period. Over this period, a total of 20 separate calibrations were performed, one calibration every three minutes and for each calibration the amplitude ratio and phase difference between the reference and test channel were measured at 100 MHz intervals over the 7 GHz bandwidth. At each frequency the rms variation of the phase and amplitude calibration data is computed and plotted as a function of frequency. These results clearly demonstrate that the system remains stable over a period of at least an hour, so that repeating the calibration once each hour would appear to be adequate for most component measurements. The worst case rms variation in phase and amplitude over this period is 0.6^{o} and 0.03 dB, respectively.

The importance of applying a dc bias to the harmonic mixers is illustrated in Fig. 4. This figure shows the relative increase in the conversion loss of the test channel harmonic mixer when the dc bias is removed. The measurements were made by calibrating the system first with the optimum bias applied, removing the bias on the test channel mixer and repeating the calibration. Note that at several frequencies over the band the increase in conversion loss is more than 10 dB.

2. Comparison of Measured Results With Those Obtained Using Impedance Standards

The lack of readily available precision impedance standards complicates the task of determining the accuracy of measurement systems operating at millimeter wavelengths. A standard of attenuation often used is the rotary vane attenuator. The wide acceptance of the rotary vane attenuator is due largely to the direct and accurate reading of attenuation and to the rather constant (attenuation independent) phase shift obtained with this device. For return loss measurements, Beatty* has suggested the use of 2-port standards

*R. W. Beatty, "2-Port λ_g Waveguide Standard of Voltage Standing-Wave Ratio," Electron. Lett. 9 24 (1973).

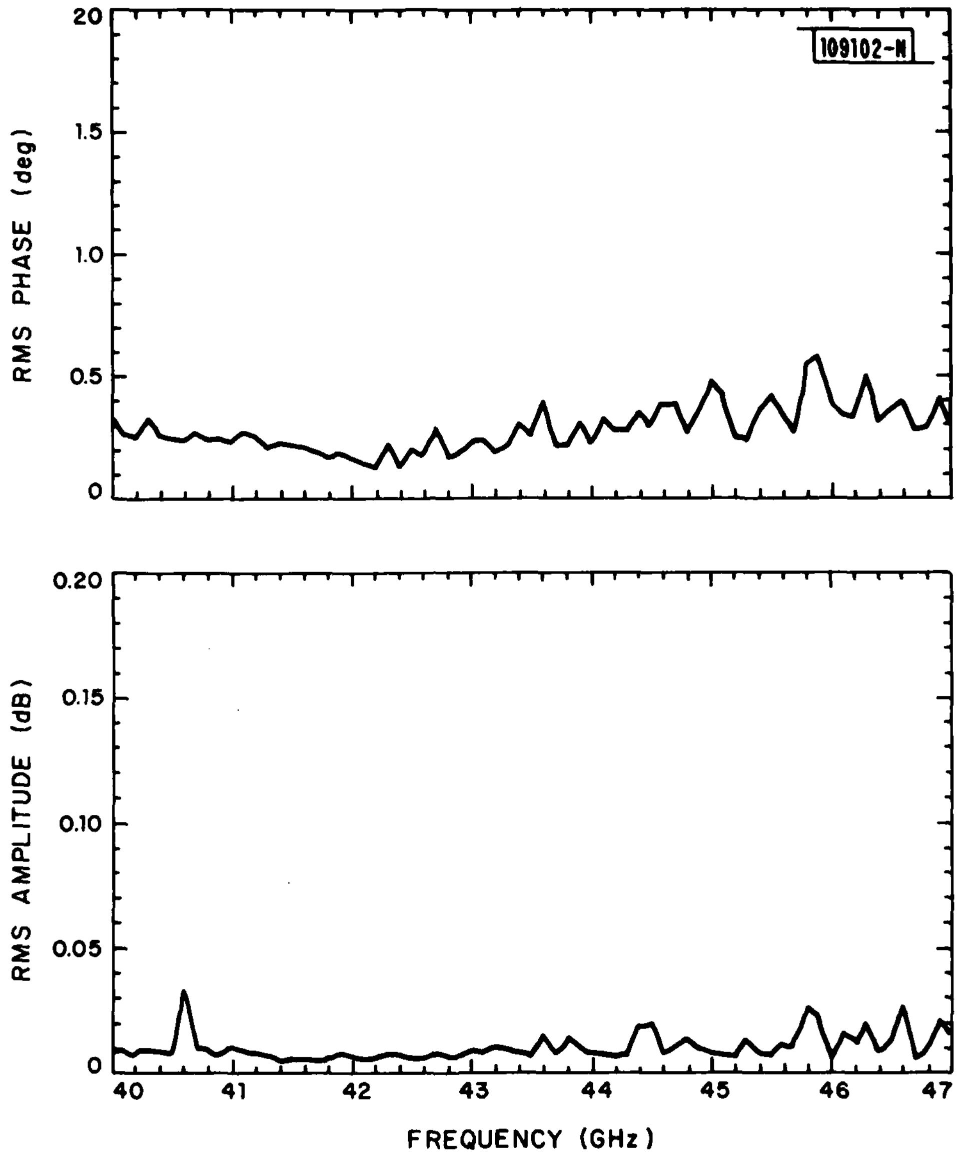

Fig. 3. Calibration results obtained over a one hour period.

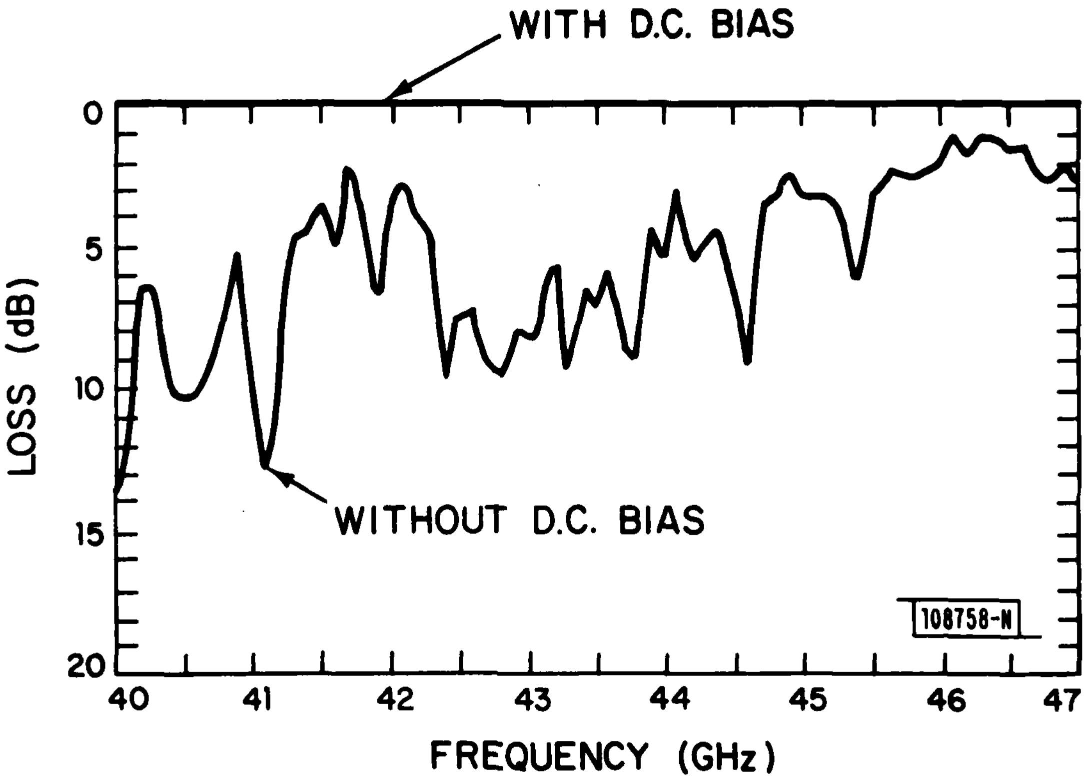

Fig. 4. Relative increase in conversion loss of the test channel harmonic mixer when the dc bias is removed.

built in reduced-height waveguide. These standards consist of a short length of guide (about $\lambda_g/4$ at the mid-frequency) in which the narrow dimension has been reduced to produce a step discontinuity whose cross-sectional dimensions are accurately known. The cross-section is chosen in a manner to give a desired calculable VSWR. When used, the standard is terminated with a standard height waveguide sliding load. The total reflection then consists of the calculable reflection from the standard, plus the residual reflection from the sliding load. The two reflections are separated by performing a series of measurements with the load in different positions.

To evaluate the accuracy of the transmission measurement data, a series of measurements were carried out using a standard, commercially available rotary vane attenuator as the attenuation standard. The system was calibrated with the attenuator in the test channel of the RTN, and set to 0 dB. At this attenuation setting the input signal level at the harmonic mixer is approximately -25 dBm. Shown in Fig. 5 are the measured values of attenuation and phase shift for a 5 dB attenuator setting. For this setting the measured values of attenuation and phase shift over the frequency band are 4.83±0.06 dB and $-0.2^{o}\pm0.5^{o}$, respectively. Measurements similar to those shown in Fig. 5 were made at other attenuation settings and the results of these measurements are tabulated in Table 1. In Table 1 it can be noted that the attenuation readings are more linear over the range from 5 to 50 dB (within .1 dB) and that they average approximately 0.2 dB less than the attenuator settings. Between the 0 dB and 5 dB settings there appears to be a slight compression in the amplitude readings (~0.15 dB) apparently due to the harmonic mixer starting to saturate at the -25 dBm (0 dB attenuator setting) level. Since the system was calibrated in the 0 dB setting, this could account for the approximate 0.2 dB offset in the attenuation measurements.

The accuracy of the return loss measurements was verified by conducting a series of tests using a set of precision, reduced-height waveguide standards. Three gold-plated, electroformed standards, having nominal VSWRs of 1.2, 1.5 and 2.0 were fabricated. After construction, the standards were carefully measured to determine their precise dimensions. These numbers were

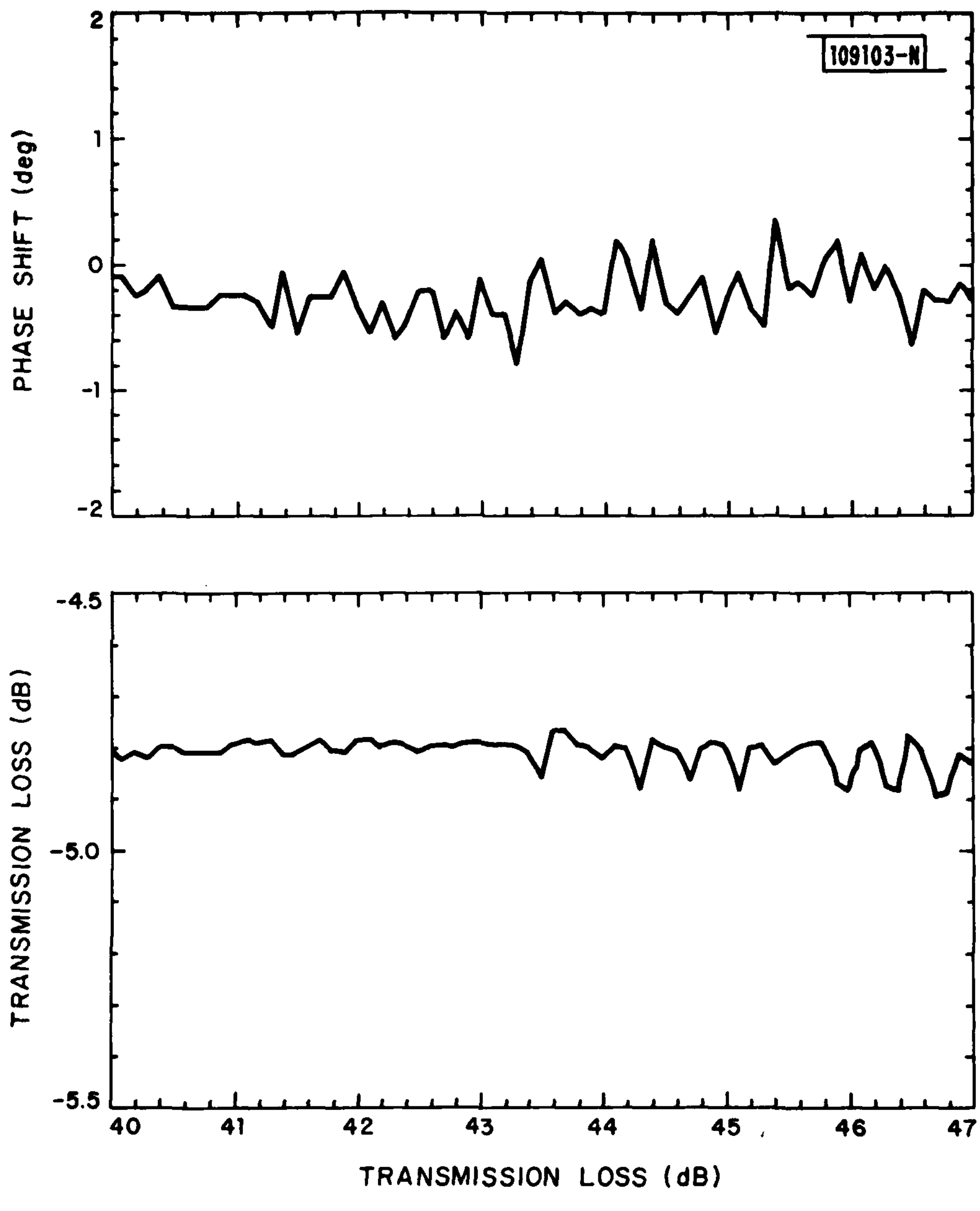

Fig. 5. Transmission loss and insertion phase measurements for a rotary vane attenuator set to 5 dB.

TABLE I

MEASURED TRANSMISSION LOSS DATA OBTAINED USING A ROTARY VANE ATTENUATOR

Attenuator Setting (dB)	Average Reading over 40-47 GHz	
	dB	degrees
0*	0±0.02	0±0.4
5	4.83±0.06	-0.2±0.5
10	9.80±0.05	-0.8±0.5
20	19.80±0.10	-1.2±0.5
30	29.80±0.10	-1.7±0.6
40	39.90±0.15	-2.0±0.7
50	49.80±0.25	-2.6±1.0

*The 0 dB setting was used in calibrating the system. The amplitude and phase variations shown for the 0 dB settings represent the repeatability of the calibration data.

then used in a computer program which calculates the complex s-parameters over the 40 to 47 GHz frequency band*. Figs. 6 through 8 show a comparison of the measured vs calculated results for the three standards. For each standard, the return loss, VSWR and the phase of the reflected signal (S11) are plotted over the 40 to 47 GHz frequency band. As these figures show, good agreement is obtained between the computed vs measured results with the difference in phase between the measured and calculated results averaging less than 1°, and the return loss difference less than 0.25 dB. As before, it is expected that part of the difference between the calculated and measured return loss data may be attributed to a slight saturation of the harmonic mixer, when the system is calibrated with a short circuit.

*The accuracy of the computed results was verified by comparison with computed results previously published by R. W. Beatty, "Calculated and Measured S11, S21 and Group Delay for Simple Types of Coaxial and Rectangular Waveguide 2-Port Standards," National Bureau of Standards, NBS Technical Note 657 (December 1974).

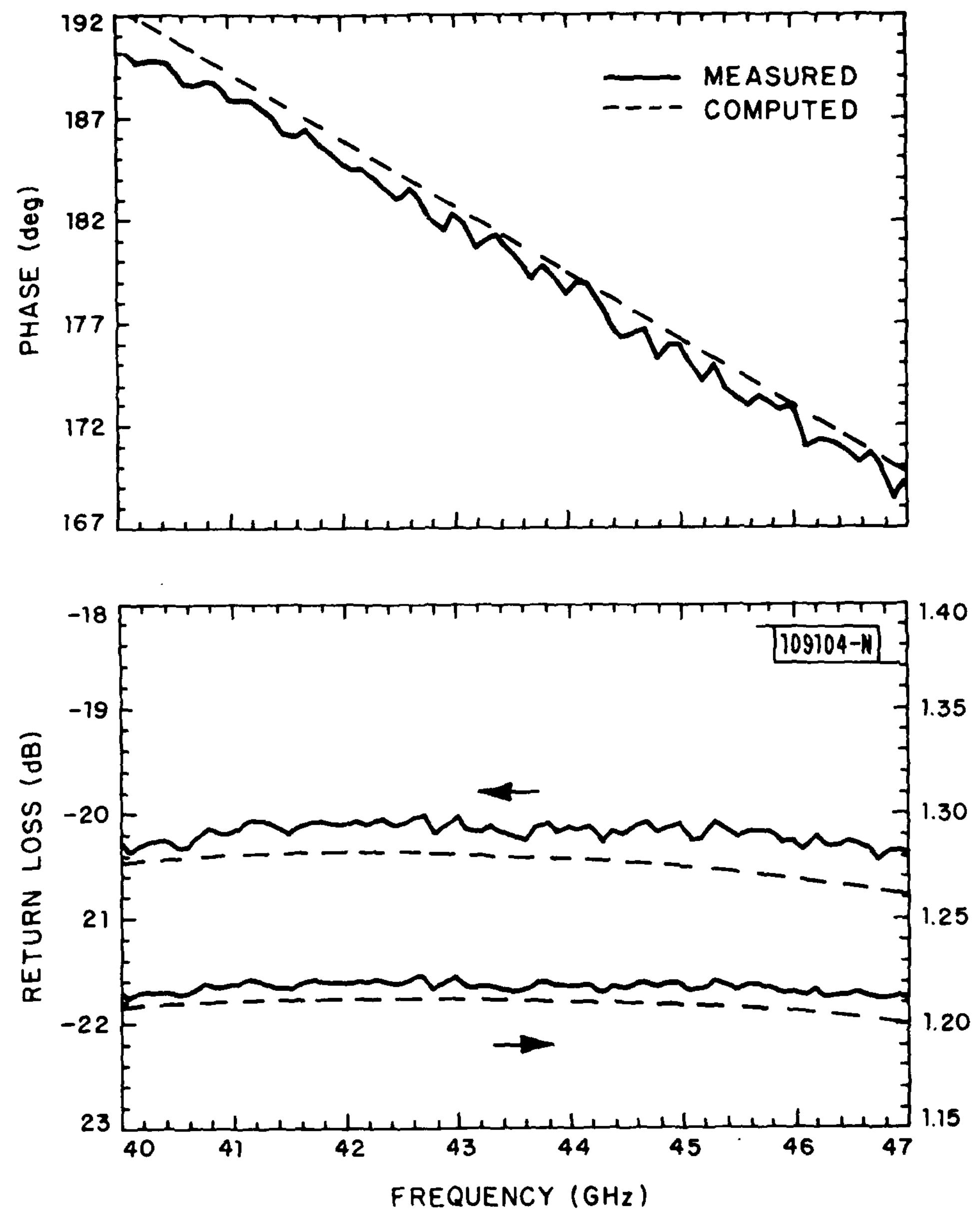

Fig. 6. Comparison of measured vs computed results for a reduced-height waveguide standard (VSWR ~1.?).

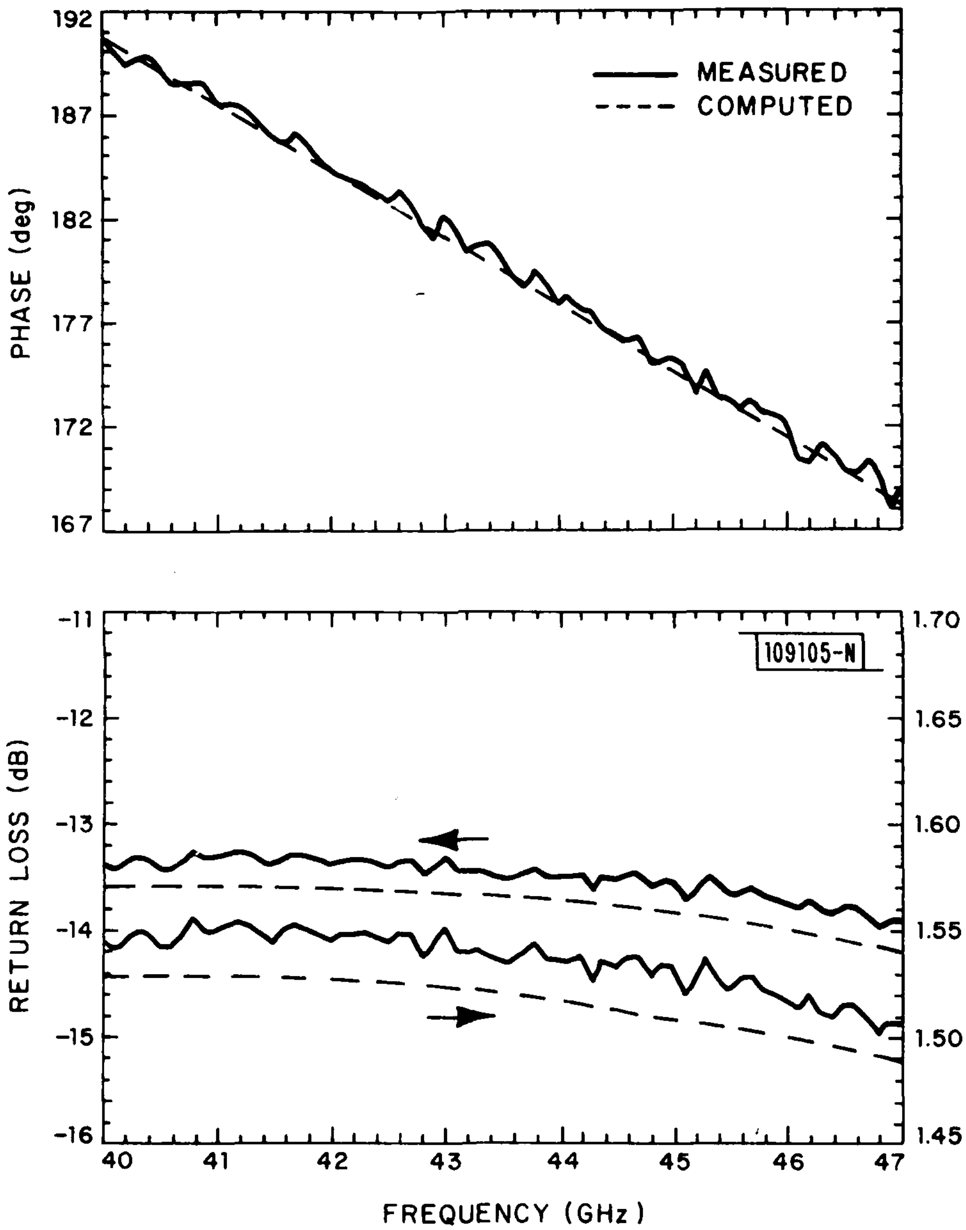

Fig. 7. Comparison of measured vs computed results for a reduced-height waveguide standard (VSWR ~1.5).

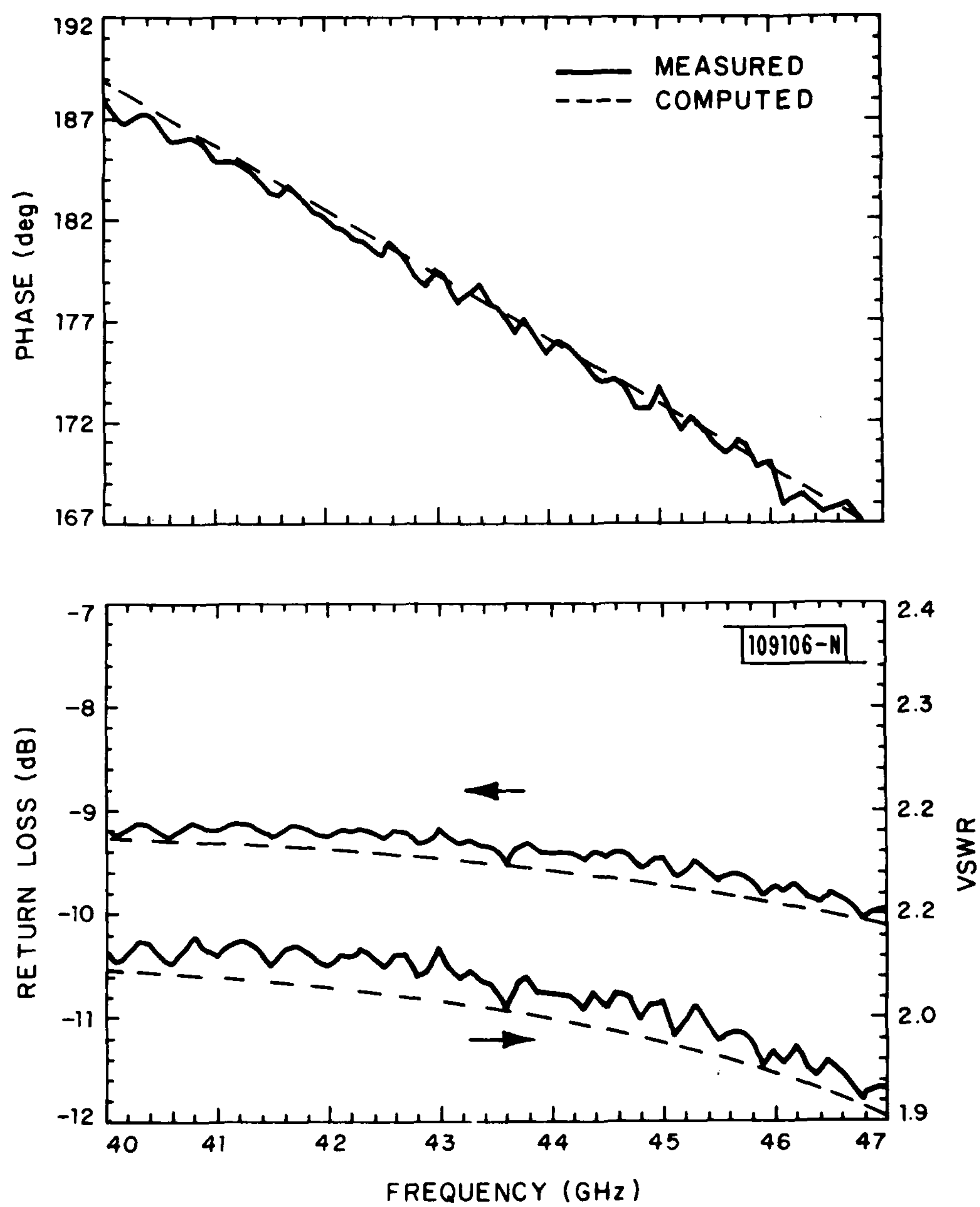

Fig. 8. Comparison of measured vs computed results for a reduced-height waveguide standard (VSWR ~2.0).

IV. DISCUSSION AND CONCLUSIONS

An automated, computer-controlled measurement system for measuring the complex transmission loss (s_{12}, s_{21}) and return loss (s_{11}, s_{22}) of components over the 40 to 47 GHz frequency range has been described. The measurement system utilizes harmonic mixing in conjunction with a phase locked, dual channel receiver to downconvert signals in the 7 GHz bandwidth to a lower intermediate frequency (1 KHz) where phase and amplitude measurement made. One of the principal advantages of using harmonic mixing is that it enables the phase/amplitude receiver to be operated over a broad range of input frequencies using selected harmonics of the 2 to 4 GHz receiver LO. In the present system configuration, frequency range limitations are the result of bandwidth limitations of the EHF source since the harmonic mixers and RTN are both capable of operating over a full waveguide frequency band. Operation at frequencies as low as 2 GHz or as high as 100 GHz or more should be possible with this receiver using suitable replacements for the EHF source, RTN and harmonic mixers.

The results of Section III have demonstrated that good performance is obtained over the 40 to 47 GHz frequency range, based upon measurements obtained with a rotary vane attenuator and reduced-height VSWR reference standards. Results obtained with these standards have indicated that measurement accuracies of 0.25 dB and 3^{o} are achievable over a 50 dB dynamic range. These estimates of measurement accuracy, however, do not include the effects of certain systematic errors such as mismatched errors or channel cross-talk, effects which can only be eliminated by going to a more complex measurement system employing error correction.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the support of numerous colleagues who have assisted in the development of this measurement system. Particular thanks are due to David Besse who was responsible for the software development and carrying out the day-to-day tasks of operating the system; to John Pineau for conducting the measurements described in Section III; to Jeff Perry for his assistance in modifying the receiver and integrating the system during the early stages of development; to Dennis Weikle and Bill Fielding for their assistance in fabricating the reduced-height waveguide standards; and, finally, to Maureen Bartlett for the typing of this report.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER ESD-TR-81-99	2. GOVT ACCESSION NO. AD-A103 547	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Automated Phase/Amplitude EHF Measurement System		5. TYPE OF REPORT & PERIOD COVERED Technical Report
		6. PERFORMING ORG. REPORT NUMBER Technical Report 560
7. AUTHOR(s) Bing M. Potts		8. CONTRACT OR GRANT NUMBER(s) F19628-80-C-0002
9. PERFORMING ORGANIZATION NAME AND ADDRESS Lincoln Laboratory, M.I.T. P.O. Box 73 Lexington, MA 02173		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element No. 63431F Project No. 2029
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Systems Command, USAF Andrews AFB Washington, DC 20331		12. REPORT DATE 28 May 1981
		13. NUMBER OF PAGES 30
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Electronic Systems Division Hanscom AFB Bedford, MA 01731		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

None

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

EHF
measurement system
EHF measurements
automated measurement system
phase and amplitude measurements

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An automated, computer-controlled measurement system capable of conducting transmission and reflection measurements on components over the 40 to 47 GHz frequency range is described. The measurement system utilizes harmonic mixing in conjunction with a phase locked, dual channel receiver to downconvert signals in the 7 GHz bandwidth to a lower intermediate frequency (1 kHz) where phase and amplitude measurements are made.

The system is capable of operating over a dynamic range in excess of 50 dB when used with an EHF source producing a minimum −10 dBm output. Following a description of the system and its operation, some performance characteristics are presented. The measurement system accuracy is demonstrated using two types of reference standards: (1) a rotary vane attenuator for the transmission measurements, and (2) a set of reduced-height waveguide VSWR standards for the return loss measurements. Results obtained using these standards have indicated that measurement accuracies of 0.25 dB and 3° are achievable over a 50 dB dynamic range.

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)